CHAPTER 3: STORMWATER MANAGEMENT MEASURES

DETENTION BASINS

As noted earlier, detention basins temporarily store stormwater before discharging it directly into a surface-water body. Until recently, the primary function of a detention pond was to try to reduce the flood peak. Little if any consideration was given to the pollutants carried by the stormwater.

For the purposes of this guidebook, three types of detention basins will be considered: dry, extended dry, and wet. Each basin can be designed to reduce flood peaks; however, their impact on stormwater quality varies for each design.

Dry Detention Basins

The dry detention basin is probably the most popular design that has been used throughout the United States. The basins are usually dry, except for short periods following large rainstorms, or snowmelt events. The basins can be in the form of excavated basins, athletic fields, parking lots, or most any storage area that has the outlet restricted in some way. If the basin can be used for something in addition to detention, the dual use allows for the recovery of the land cost.

The primary function of the dry detention basin has been as a flood-control device to reduce flood peaks, reduce downstream flood elevations, and to some degree reduce downstream erosion. The National Urban Runoff Program (NURP, Reference 51) monitored dry detention basins and found them to have very little impact on water quality. Sedimentation may occur in the basins; however, later runoff events will scour the bottom and move the sediments downstream. If water quality improvement is an objective in a watershed, a dry detention basin is **not** a recommended best management practice.

Extended Detention Basins (See figure 3.1)

The U.S. Environmenatal Protection Agency found that by modifying the outlets of dry detention basins, it was possible to achieve water quality benefits. The outlet modification results in the basins containing water for most storms. About 1 to 2 days after a storm, the basin will be drained. The purpose of the extended detention basin is to increase the time the stormwater will remain in the detention basin, which will result in more pollutants settling out. However, the sediment must be removed regularly, to prevent the re-suspension of pollutants by future runoff events. These basins are **not** effective at removing nutrients that are soluble, such as phosphorus and nitrogen. Even though extended detention basins empty following a storm, they may have a particulate pollutant removal rate of up to 90%, yet the basin will likely cost only about 10% more than a "conventional" dry detention basin. Thus for a little extra money, there can be a great potential for improving the downstream water quality.

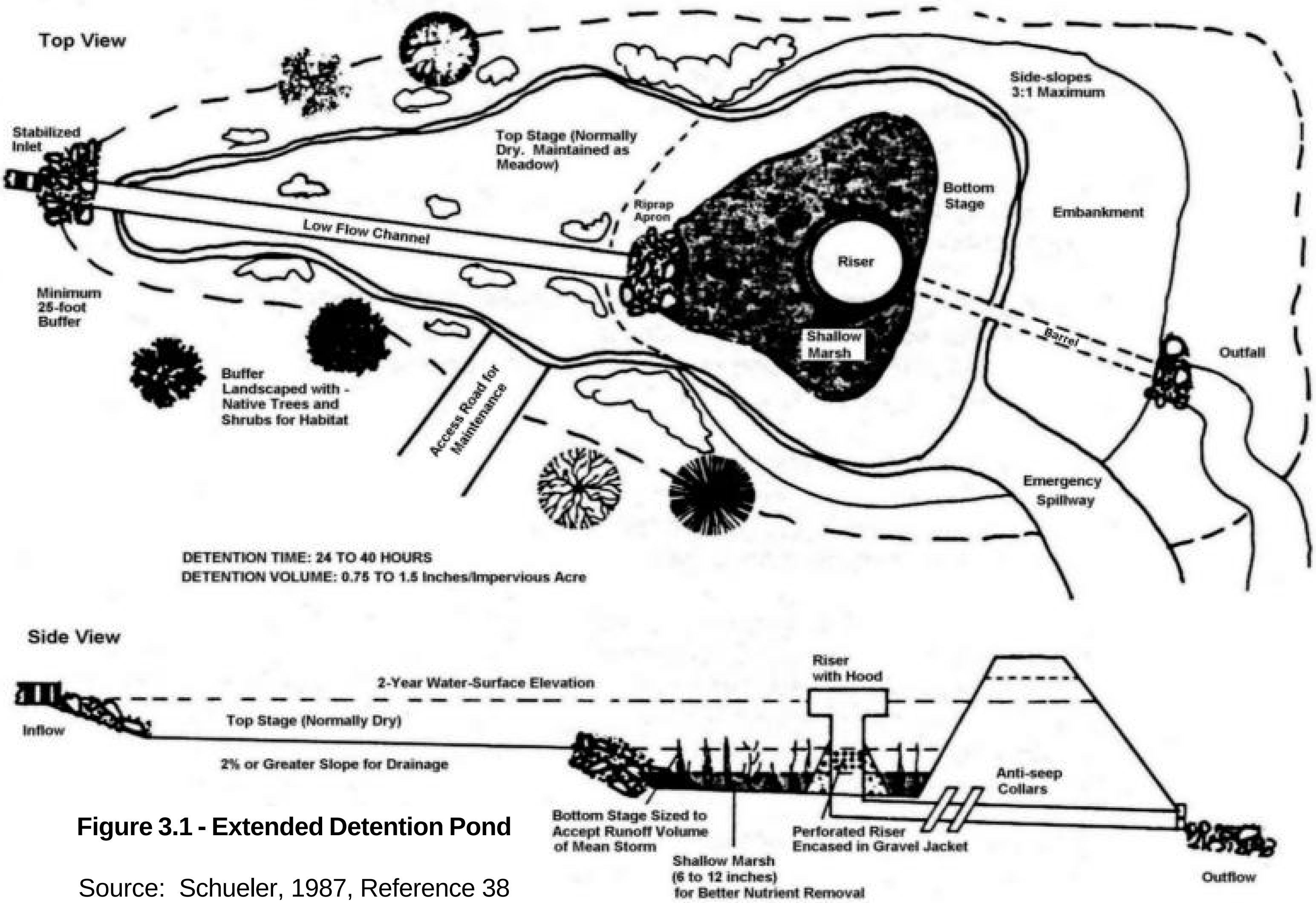

Figure 3.1 - Extended Detention Pond

Source: Schueler, 1987, Reference 38

Following are some guidelines for the design of extended detention basins:

1. **Basin Volume**

The volume of storage required within a basin is dependant upon the function that the basin will be expected to perform. If water quality is the primary concern, there are various methods that are utilized in other regions. A straightforward method requires a storage volume that is equal to <u>one-half</u> <u>inch</u> <u>of</u> <u>runoff</u> from the contributing watershed. (For residential areas, 1/2 inch of runoff would be about a 1 -year rainfall event in Michigan). For the high percentage of particulate pollutant removal, the detention basin should be designed so that it will take at least 24 hours to drain the entire volume stored (Reference 38).

Extra volume should also be provided to account for sediment build-up over a 5 to 10 -year period.

If water <u>quantity</u> is also a concern, it will be necessary to determine what flood protection is desired. The volume of storage to provide 2 -year protection will be significantly less than for a 100-year storm. Later in the guidebook stormwater <u>quantity</u> volumes and flow rates will be reviewed.

2. **Basin Configuration**

The basin shape is about three to five times as long as it is wide. It is also advisable to be narrow at the inlet and wide near the outlet (See figure 3.1).

When both water quantity and quality concerns are to be considered in the design of the extended detention basin, the basin can be designed using a two-stage concept. The lower stage would be designed to be wet frequently and would function as a wetland or shallow pond. This lower stage is designed to contain the water "quality" volume noted above. The upper stage of the basin would be designed to contain the water "quantity" volume. Figure 3.1 shows a typical configuration of a "two -stage" extended detention basin.

The upper stage of the basin should be sloped at a grade of about 2% or more, so it drains well and can be maintained as a meadow-type land -use. Since the lower stage will be wet frequently, it could be maintained as a wetland.

3. **Side slopes**

The side slopes leading to the detention basin should be no steeper than 3:1 (horizontal:vertical) and no less than 20:1 to provide for easy maintenance and to insure proper drainage to the pond. Slopes flatter than 20:1 may result in wet areas that will make maintenance difficult. The slope within the lower stage of the basin should be relatively steep, about 3:1, to minimize the frequently wetted land surface.

4. **Buffer Area**

Surrounding the pond there should be at least a 25 -foot buffer area that is planted with shrubs, trees and low maintenance grasses. The buffer area may improve the "appearance" of the basin, and may also provide a potential habitat for wildlife.

5. **Low-flow channel**

If the basin is to be dry the majority of the time, it will be necessary to provide a low -flow channel through the basin. The channel should be lined with rip -rap to prevent scour. The basin storage area should drain toward the low flow channel so the area may be used and maintained when not flooded.

6. **Outlet Control**

The most common outlet control device for extended detention basins typically consists of a vertical corrugated metal pipe (cmp) that has been perforated with holes that are generally 1 to 2 inches in diameter. The tube is surrounded by wire mesh and gravel larger than the size of the perforations to prevent clogging (see figure 3.2). The riser will overflow only when the design volume has been exceeded. (As an example, set the top of the riser equal to the elevation of the pond needed to store 1/2 inch of runoff from the watershed draining into the detention basin.)

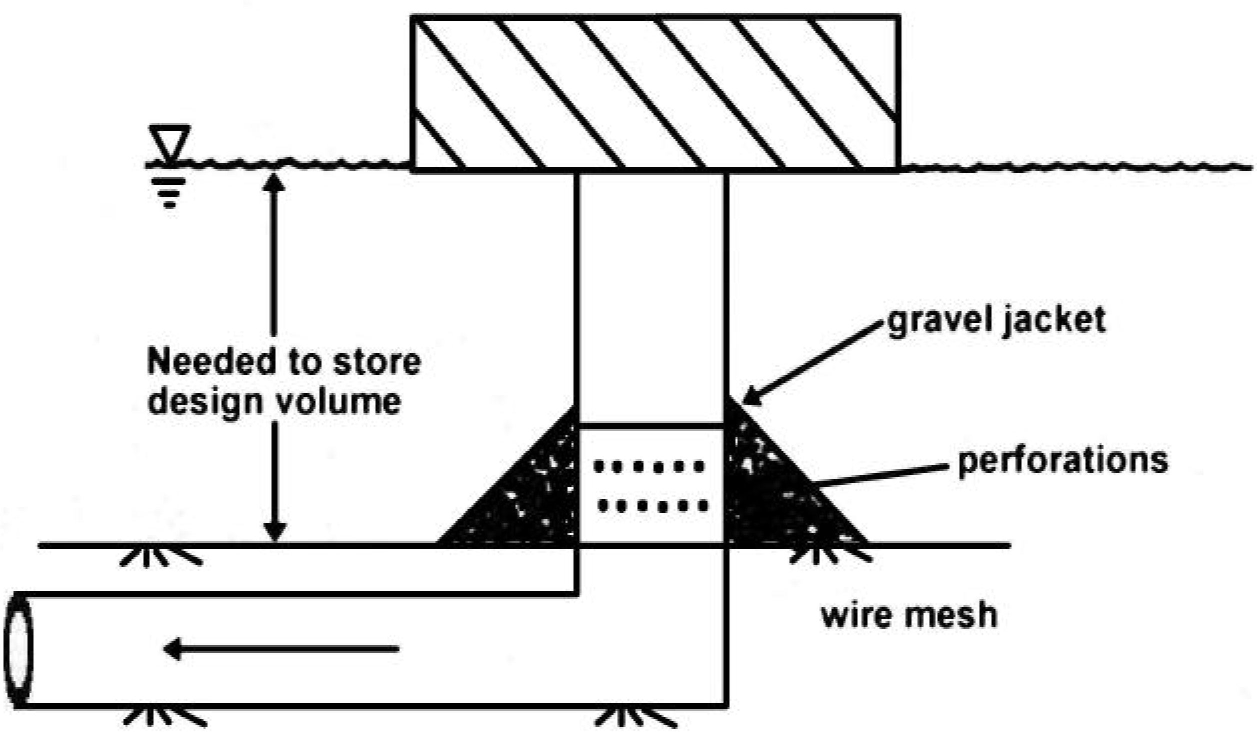

Figure 3.2 - Perforated Riser

Later in the guidebook the design of outlet structures will be discussed in greater detail. However, the rate of outflow can be estimated using the following equation:

$$Q_{out} = [(V)43560]/ 3600 (T) \qquad (1)$$

where: **Q_{out}** - outflow in cubic feet per second, cfs
V - design runoff volume to basin, Acre-feet
43560 - square feet per acre
T - detention time, hours; a minimum of 24 hours is suggested
3600 - conversion from hours to seconds

Using a 24-hour detention time, the equation is reduced to:

$$Q_{out} = 0.504 V \qquad (2)$$

To estimate the amount of outlet area required to carry the design outflow, it is possible to use the following equation for orifice flow:

$$Q_{out} = CA (2gh)^{.5} \qquad (3)$$

where: **Q_{out}** - outflow, cfs, as estimated above
C - discharge coefficient, for circular perforations, a C of 0.6 is a reasonable value. (See reference 27)
A - Area of openings (perforations)
g - acceleration due to gravity, 32.2 feet/sec
h - average height of water above the openings (see figure 3.3a)

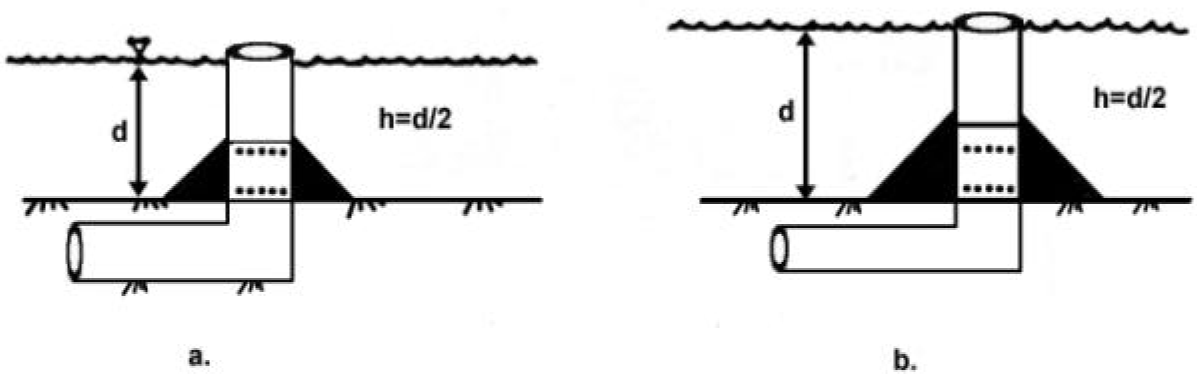

Figure 3.3 - Average height (h) for a perforated pipe outlet structure

Since the water elevation within the basin will be constantly changing as the water flows out of the basin, "h" will not be constant. As an estimate "h" can be taken to be equal to 1/2 the depth of water above the opening. (It must be noted that using this average "h" will result in an "average" discharge; this will **not** determine the **peak** discharge. If peak outflow is a concern, the design elevation for the basin must be used to determine the "h".)

Rearranging equation (3), and inserting the constants, the area of the perforations can be estimated to be:

$$Q_{out}/A = (.6)(64.4 h)^{.5} \qquad (4)$$

Example 3.1 - Given a 100-acre parcel with a water quality design criteria of storing 1/2 inch of runoff, determine:

(a) volume of runoff required to store
(b) the design outflow, using a 24-hour detention time
(c) an estimate of the total number of 2-inch circular perforations required (water surface for design storage is 4 feet above the center of the outlet, in figure 3.3a, d= 4 feet).

a. **Volume of runoff** = 100 acres x 1/2 in. x 1 ft/12 in. = **4.2 acre-feet**

b. Using equation (2), Q_{out} = (.504 cfs/acre-foot)V
Design outflow (Q_{out}) = .504 (4.2 acre-feet) = **2.1 cfs**

c. Using equation (4), $Q_{out}/A = (.6)64.4h)^{.5}$

(note: H is one-half of the distance from the center of the perforation to the design water surface, as shown on figure 3.3a. For this example h = d/2 = 4/2 = 2)

Total area required = 2.1/A =$(.6)\{(64.4)(2)\}^{.5}$

= 2.1/A = 6.81

A = 2.1/6.81 = **.308 sq. feet**

The perforations will be 2-inch circular holes, thus the total number of perforations can be estimated to be:

For a circle: $A = \frac{Pi(D)^2}{4}$; $\mathbf{A_{total}} = \frac{(n)Pi(D)^2}{4}$; (5)

where: **A_{total}** - total area of all of the perforations
Pi - a constant of 3.14156
D - the diameter of the perforation, ft
n - number of perforations

by rearranging:(5) $n = \frac{4\,A_{total}}{Pi\,D^2}$

Using equation (5) for the example above:

$$n = \frac{(4)\ .308 \text{ square feet}}{3.14(.167)^2} = 14.1,$$ **use 15 perforations**

There are no specific design guidelines associated with the spacing of the perforations in the riser pipe. It is suggested that the spacing between the perforations be at least one and one-half to three times the diameter of the perforation.

If all of the perforations cannot be made on one row of the riser pipe, the "h" in equation (4) will not be the same for each row of perforations (See figure 3.3b). It may be necessary to re-estimate the area needed to achieve the computed outflow, using an "h" that is centered on the rows of perforations.

For flows exceeding the water quality design flow, principal and emergency spillways must be provided to prevent overtopping of the embankments.

7. **Cost**

A cost study in Washington, D.C. (Wiegand et al, 1986) derived the following rough cost estimate for the construction of a dry extended detention basin, greater than 10,000 cubic feet:

$$C = 10.71\ V^{.75}$$

where: **C** = construction cost in 1985 dollars
V = volume of storage (cubic feet), including the permanent pool, up to the crest of the emergency spillway

As an example, if 30,000 cubic feet of storage is to be provided, the estimated cost in 1985 dollars is about:

$$C = 10.71\ (30{,}000)^{.75} = \$\ 13{,}200$$

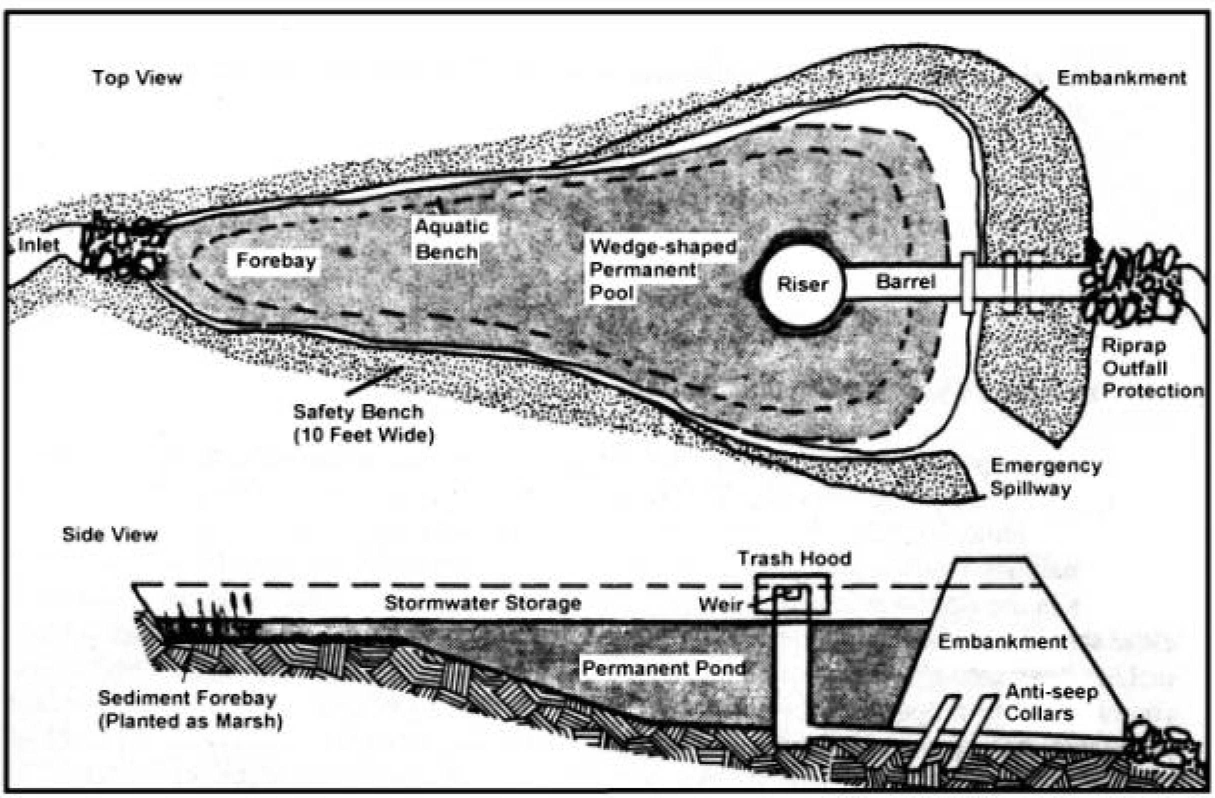

Figure 3.4 - Wet Detention Pond

(Source: Schueler, 1987, reference 38)

Wet Detention Ponds (See figure 3.4)

Of the three types of detention basins, the wet pond is the most effective at removing sediment and pollutants, including nutrients. The biological processes (algae and plant life) make the pond effective at removing nutrients, unlike dry and extended detention basins. Since wet detention basins maintain a permanent pool of water, there is a possibility of algae forming due to the nutrients in the stormwater. For the wet pond to remain effective at removing the nutrients, the algae should be removed regularly. Typical methods of controlling algae and other aquatic plants include "harvesting," dewatering, or herbicides. The use of herbicides is contrary to the purpose of the wet detention pond. The intention of the pond is to remove pollutants, not introduce additional pollutants. If no other alternative is available, herbicides must be applied with extreme caution to prevent contamination of receiving waters. The application of herbicides in surface waters will require a permit from the Michigan Department of Environmental Quality, Land and Water Management Division, Inland Lakes and Wetlands Unit (telephone # (517) 373-1746).

If a watershed is experiencing problems with nutrients within the stormwater runoff, a wet detention pond is really the only detention design that will provide some removal of the nutrients.

Following are some of the design guidelines for wet detention basins, for water quality purposes:

1. **Basin Surface Area**

The surface area of the basin is critical in allowing particles to settle out. The following table gives a rough estimate of the permanent pool's surface area expressed as a percentage of the area draining into the pond, the land use in the watershed, and the size of particles that will be settled out. As a point of reference for particle size, fine sand is about 40 to 100 microns, silt is about 10 microns, and clay is about 1 micron.

The 5-micron control listed will capture all particles greater than 5 microns in size, or about 90% of the particulates in urban runoff. It should be noted that some studies indicate that 10 microns is about the smallest size portion that could be expected to settle out in the "field". A 20-micron control will capture about 65% of the particulates.

Table 3.1 - Basin Size Expressed in Percent of Drainage Area

	Particle Control Size	
Land Use	**5 micron**	**20 micron**
Freeways	2.8%	1.0%
Industrial	2.0%	0.8%
Commercial	1.7%	0.6%
Institutional	1.7%	0.6%
Residential	0.8%	0.3%
Open Space	0.6%	0.2%

Source: Reference 33

As an example, a 100-acre residential subdivision would require a surface area of about 0.8 acres of wet detention to capture particles larger than 5 microns. (From table 3.1, residential land use for 5-micron control shows a basin area that is 0.8% of the total drainage area. Hence, 100 Acres x 0.008= 0.8 Acres). If the same parcel were industrial, and the same 5-micron control were desired, the basin surface area would have to be about 2.0 acres.

Of course, Table 3.1 is just an initial sizing estimate for water quality purposes. Additional information on runoff volume and outflow rates will have to be considered.

2. **Basin Volume**

There are various methods used in estimating the volume required in a wet detention basin, designed for **water quality** purposes. Each of the methods provides moderate levels of sediment removal. The design of a wet pond will require a water-quality volume to be computed. The water-quality volume is stored above the permanent pool (see figure 3.4). To achieve pollutant removal, the permanent volume of the wet pond should also be equal to or greater than the water quality volume. If flood control is also a prime concern, a water-**quantity** volume must be computed. The storage required for water quality concerns will be discussed later. For the purposes of this guidebook, the four following methods of computing the **water-quality volume** are discussed.

a) **First-flush method**. Probably the most common method used to estimate the size of a detention basin is the "first flush" method. With this criterion, the basin volume required is determined using 1/2 inch of runoff per impervious acre of the land draining to the basin.

   If a 100-acre site has 38 acres that are impervious, a detention basin would require 1.6 acre-feet of storage (38 acres x .5 inch/acre x 1-foot/12 inches).

   A variation of this method involves using 1 inch of runoff per impervious acre. In essence, this variation doubles the volume requirement of the detention basin. In the example above, the storage requirement would have been 3.2 acre-feet instead of 1.6 acre-feet.

b) **Runoff method**. A simple method to apply involves using one -half inch of runoff for the entire drainage basin. As an example, a 100-acre site would require 4.2 acre -feet of storage. (100 acres x 0.5 inch/acre x 1 foot/12 inches)

   This method does not give credit for low runoff (pervious) surfaces within the watershed. A watershed that is heavily industrialized would have the same water-quality volume requirements as a residential development.

   The other methods discussed in the guidebook are dependent on land-use. Thus as the land use changes, the volume requirements will also change. The "runoff method" would remain at 1/2-inch runoff regardless of land-use.

c) **Design-storm method**. Basin volume is equal to the runoff produced by a selected design storm. One possibility is the use of a 1 -year, 24-hour duration storm. (Appendix B lists various storm frequencies for the counties of Michigan). This method will require that the land use and soil types be determined for the watershed, in addition to the rainfall amount.

For residential developments, a 1-year, 24-hour duration storm method would be similar to assuming between 0.5 and 1 inch of runoff from the entire drainage area. For industrial and commercial areas, a 1-year storm could produce over 1.5 inches of runoff.

d) **Mean Storm volume**. The basin volume is determined to be a multiple of the mean storm runoff volume, when only the impervious acres are considered. Mean storm volume is defined as the volume runoff produced by the mean rainfall event. Studies have indicated basin volumes that exceed 3 times the mean storm runoff volume yield, diminishing returns. The mean storm volume is determined by a statistical analysis of the rainfall data for the area.

For Lansing, the mean storm volume is approximately 0.3 inches, (reference 54). This value varies across the state; however, 0.3 inches is a reasonable estimate if rain gage information is not available. If a 100-acre parcel has 38 impervious acres, and the runoff coefficient for the impervious area is 0.95, the mean runoff volume for the parcel is estimated to be:

(38 acres x 0.95 x 0.3 in. x 1 ft/12 in.) = 0.90 acre -ft

The basin volume requirement is estimated to be three times the mean runoff volume from the impervious area:

Basin volume = 0.90 acre-feet x 3 = **2.7 acre-feet**

In general, the larger the pond the more efficient the pond will be at removing the pollutants. Since there is a cost factor involved, at some point, the extra cost associated with a larger basin does not significantly increase the efficiency of the basin. Studies have indicated that basins which have a volume more than 3 times the mean runoff volume have diminishing returns on the money invested.

Each design method will provide different results to be used to size the detention basin. The table on the next page provides a comparison of the four methods for a 100-acre parcel in Lansing, Michigan. For each runoff method, four different land use types have been considered. Following are the four land use types and the corresponding percentage of the total drainage basin that is impervious: commercial/business districts, 85% impervious; industrial areas, 72% impervious; 1/4 acre residential, 38% impervious; and 1/2 acre residential, 25% impervious.

From table 3.2, it can be seen that a wide range of storage volumes can be computed depending on the runoff criteria used. As noted earlier, storage volumes exceeding three times the mean runoff volume have a diminishing return on the cost of the basin. Thus, from a water-quality standpoint, three times the mean runoff volume could be thought of as the upper limit, and the first flush method would represent the lower limit of the volume requirements.

It is not the purpose of this guidebook to provide a method that should be used in all communities, but to present methods that are currently in use throughout the United States.

Actual criteria should be established at the local level. The 0.5 inch of runoff for the entire watershed is the simplest method to administer. However, from a water- quality aspect, this method will be very conservative in residential areas.

Table 3.2 - Detention Basin Storage Volume (acre-feet)
Comparison of different runoff methods
For a 100-acre site in Lansing, Michigan

Percent Impervious	First-Flush Method	Runoff Method	Mean Runoff Volume x 3 Method	One-Year Design Storm Method
85	3.5 A.ft.	4.2 A.ft.	6.1 A.ft.	13.2 A.ft.
72	3.0	4.2	5.1	11.2
38	1.6	4.2	2.7	4.5
25	1.0	4.2	1.8	2.1

3. **Basin Depth**

To prevent scouring and resuspension of sediments, the basin pond should be permanently 4 to 6 feet deep over most of the basin. The depth will also minimize the growth of aquatic plants and may allow the planting of small fish and minnows that eat algae and mosquitoes. Depths less than 3 feet may result in scour, while depths greater than 6 to 8 feet may result in thermal stratification and water-quality problems.

Near the basin inlets, extra depth may be constructed to provide sediment storage capacity. It is much cheaper to initially provide extra storage than it is to dredge out accumulated sediment.

4. **Basin Shape**

The basin shape should allow for good circulation and easy maintenance. If the shape is not adequately considered, "short circuiting" may occur. When short circuiting occurs, the incoming water does not displace the "old water" already in the basin. Instead, the incoming water passes right through the basin with minimal pollutant removal, as a result, water quality is not improved. It is recommended that the flow length from inlet to outlet be about three to five times the width of the pond. If it is not feasible to construct a basin with such dimensions, baffles should be used to achieve the flow path length. (Figure 3.5 provides some examples of short circuiting, baffles to increase flow path, and a recommended shape.)

The most common pond configuration is wedge shaped, narrow at the inlet and wide near the outlet. Such a shape allows for good circulation. The pond shape should also be irregular to achieve a "natural" look that will fit in with the surroundings. However, in achieving the "irregularity", care should be taken to not create areas that will prohibit the circulation of water.

If the basin is functioning properly, it will be necessary to provide some maintenance dredging to remove accumulated sediments. Thus, the pond shape should also consider future maintenance needs. As an example, a long narrow pond may be easier to dredge, than a circular pond.

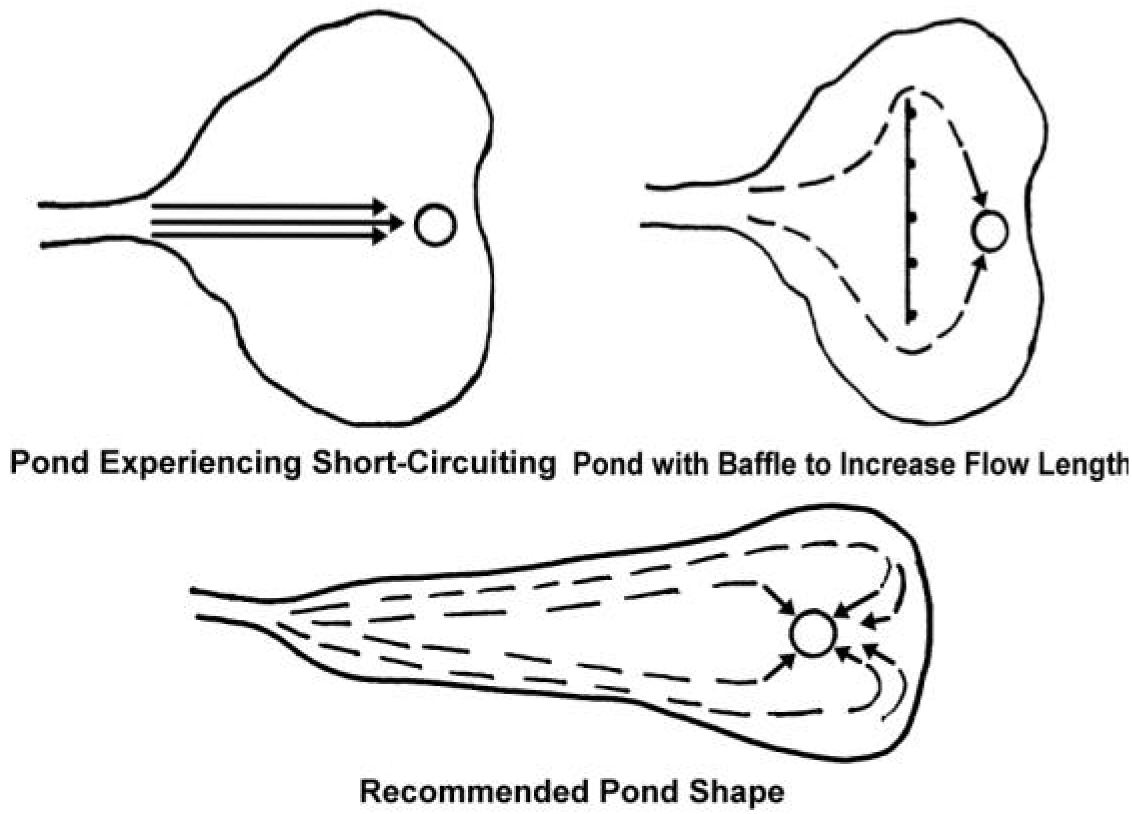

Figure 3.5 - Examples of Water Circulation within a Detention Basin

5. **Side-slopes**

Figure 3.6 shows a suggested configuration for the side slopes of a wet detention basin. The perimeter of the pond should be surrounded by a relatively flat shelf that is at least 10 feet wide. A permanent pool of water, about 1/2 foot to 1-1/2 feet deep, should cover the perimeter shelf. The shelf should be planted with rooted aquatic plants. The primary purpose of the plants is to act as a vegetative barrier to prevent easy access to deeper water to discourage swimming. However, the plants also provide a "natural" appearance to the basin. The side slope leading to the pond shelf should be at a relatively steep slope of about 3:1 (h:v). Such a slope will result in less land being frequently inundated, and thus will reduce the mosquito problems. The 3:1 slope should be continued up to the water level elevation anticipated for the water quality design storm (such as 0.5 inches of runoff). The side slope from the basin shelf to deep water should be 3:1 maximum.

The side slope up to the elevation that will contain the design flood (as an example a 10-year flood) is suggested to range from 4:1 to 20:1 depending on the area available. A side slope of no less than 20:1 will provide an area that is easy to maintain and will drain well. These side slopes should be planted with water-tolerant grasses, shrubs, and trees and should be maintained as a meadow. It is important to note that trees should not be planted on any filled embankments that were created to impound water. The roots of the trees will provide seepage paths for water during impoundment, which may lead to a failure of the embankment.

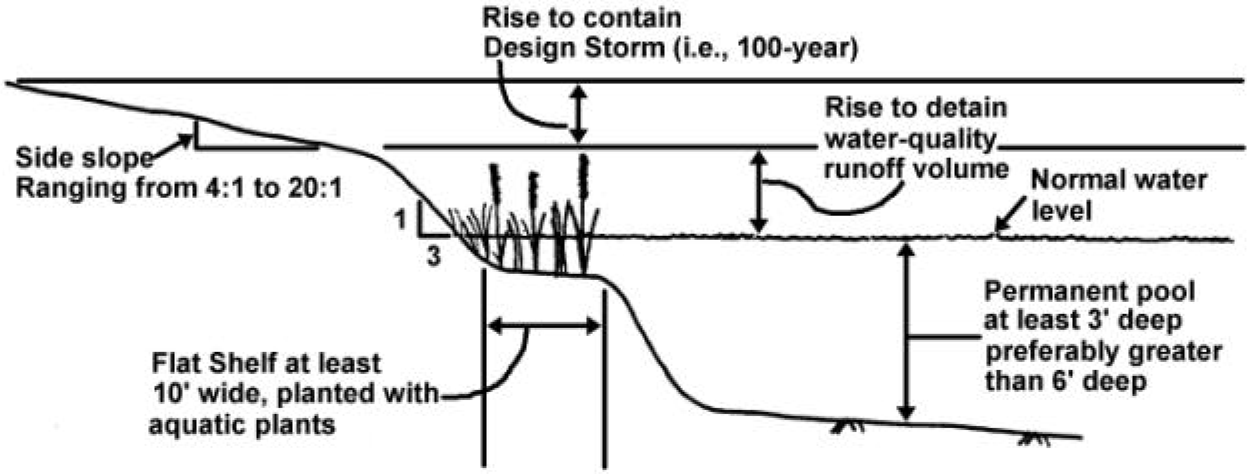

Figure 3.6 - Typical Wet Detention Pond Cross Section

6. **Cost**

A cost study in Washington, D.C. (Reference 56) derived the following rough cost estimate for the construction of a wet detention pond, less than 100,000 cubic feet:

$$C = 6.1\ V^{.75}$$

where: **C** = construction cost in 1985 dollars
V = volume of storage (cubic feet), including the permanent pool, up to the crest of the emergency spillway

For ponds greater than 100,000 cubic feet, a rough cost estimate would be:

$$C = 34\ V^{.64}$$

The estimate does not include land costs, only construction costs are included. An additional 25% may be added to the estimated cost to try to account for contingencies, inspections, and costs of securing permits.

It must be remembered that these cost estimates are only for initial planning purposes, and are **not** to be considered final estimates.

7. **Outlet Rate For Water-Quality Purposes**

The outflow from a detention pond will be restricted to achieve the necessary water-quality and quantity benefits. The outlet structure must be designed to achieve the desired results.

Later in this guidebook, flood-control considerations will be reviewed. The following discussion is in regard to the water- **quality** requirements.

Two critical factors in determining the effectiveness of the removal of particulates in wet detention basins are the settling velocity of the particulate and the velocity within the basin.

For a particulate to be removed from suspension in a detention basin, the settling velocity must be great enough for the particulate to fall below the outlet elevation before it reaches the outlet (See figure 3.7). Particulates that do not settle fast enough are kept in suspension and will flow from the outlet. It can be generalized that the slower the velocity within the basin, the smaller the particulates that will settle out. For higher velocities, only the large particulates will settle before they reach the outlet.

From figure 3.7, a particulate will travel a distance of L at a horizontal velocity of V, in a time of t (L = vt). The same particulate will settle a vertical distance of D at a vertical (settling) velocity of v in a time of t (D = vt). For a particulate to be retained in the basin, the time it takes to travel a distance of L must be greater than or equal to the time it takes to settle the distance D.

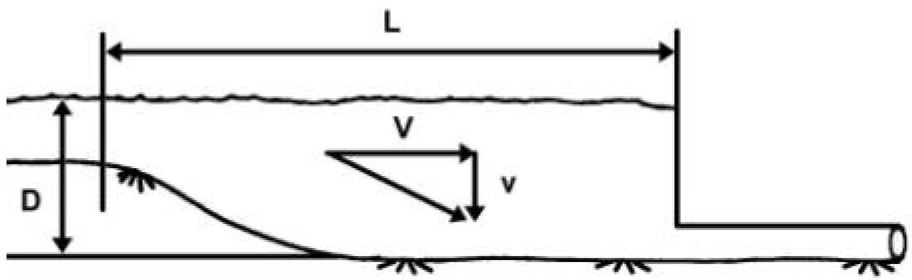

Figure 3.7 - Settling Velocity and Pond Dimension

(adopted from references 25 and 33)

In other words, the particulate must settle below the outlet elevation before it reaches the outlet. The largest particulate that will be captured by the basin, will be the particulate that travels the distance L in the same time that it takes to settle distance D. It can be shown that:

$$t = L / V, \text{ and } t = D/v; \text{ or}$$
$$L / V = D/v \qquad (6)$$

where: **t** - is the time it takes for the particle to settle
L - length of the basin
D - depth of the basin
V - horizontal velocity component
v - critical settling velocity

rearranging equation (6) :

$$v = VD/L;$$

multiplying by basin width **W**:

$$v = VDW/LW$$

DW represents the cross-sectional area of the basin. Area (DW) times velocity (V) is equal to discharge out (Q_{out}):

$$v = Q_{out}/LW \tag{7}$$

The surface area of the basin (A) is defined by length (L) times width (W), thus:

$$v = Q_{out}/A \tag{8}$$

where: **v** - critical settling velocity in feet per second
Q_{out} - Outflow from the basin in cubic feet per second
A - is the surface area of the detention basin, in square feet.

Linsley and Franzini (reference 25) define Q_{out}/A as the overflow rate.

From equation (8), it can be seen that the critical settling velocity is a function of the outflow rate and detention basin surface area. It is also interesting to note that increasing the depth of a basin does **not** increase the efficiency of the basin. (However, increasing the basin depth does reduce the possibility of scour, provides additional volume to accumulate sediment, limits winter fish kill, and reduces the amount of attached aquatic plants). To remove smaller size particulates, it would be necessary to either decrease the outflow rate or increase the basin surface area.

If equation (8) is rearranged:

$$Q_{out} = Av \tag{9}$$

The settling velocity of a particulate is a function of particle density, size, and shape as well as the density of the liquid (water). Studies have shown that the densities of particulates in stormwater runoff vary considerably, from 2650 kilograms/cubic meter (kg/m^3) to 1100 kg/m^3 (reference 41). (Note: Water has a density of about 1000 kg/m^3.) Since the density can vary so much, the settling velocity of particulates can vary significantly. The settling velocity of particulates can be site specific. The most appropriate method would require the sampling of particulates contained in runoff from a specific site.

If sampling information is not available, figure 3.8 provides an estimate of settling velocity, based on particle size. The figure has been developed assuming a particle density of 1500 kg/m^3, and a water temperature of 68^oF.

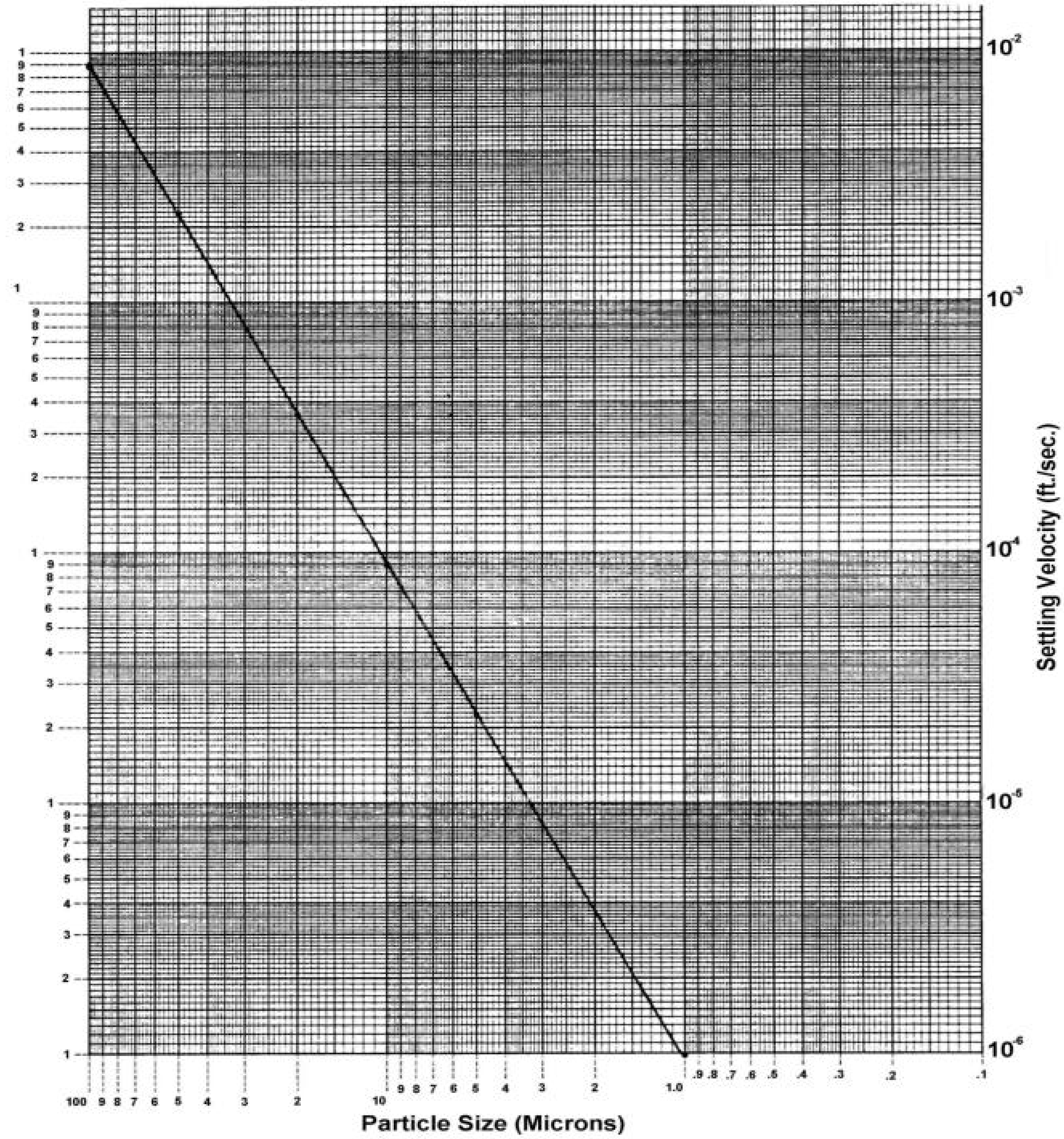

Figure 3.8 - Settling Velocity for Stormwater Runoff Particles

The following example illustrates how table 3.1 and figure 3.8 may be used in the design of a wet pond for water-quality purposes.

Example 3.2. Given a 100-acre industrial site for which 5-micron control is desired, find (a) required surface area; and (b) the maximum outflow rate.

a) From **Table 3.1**, to achieve 5-micron control for an industrial site, the **surface area** required is:

   2% of the drainage area, or; .02 x 100 acres = **2 acres**

b) From **Figure 3.8** the **settling velocity** of a 5-micron particle is:

   $v = 2.3 \times 10^{-5}$ ft/sec

   Using equation (9), the **maximum** outflow needed to achieve 5-micron control is:

   $Q_{out} = Av$

   Q_{out} = 2 acres x 43560 sq.ft./ acre x 2.3×10^{-5} ft/sec

   $\mathbf{Q_{out}}$ = 2.1 cubic feet/sec (cfs)

With the **maximum** outflow known, it is possible to design an outlet structure that will restrict the outflow to less than 2.1 cfs, at the water elevation needed to store the water **quality** portion of the runoff. The typical wet pond cross section shown in figure 3.6, shows the rise in the pond needed to store the water-quality runoff volume.

TYPICAL OUTLET STRUCTURE CONFIGURATION

The outlet for the wet detention basin typically consists of an outlet tube with a riser (See figure 3.4) or a weir configuration. In addition to the outlet pipe, it will also be necessary to include an emergency spillway to safely handle flows that will exceed the capacity of the outlet structure.

If an increase in downstream water temperature is a concern, it may be necessary to consider a subsurface outlet structure (See figure 3.9). The inlet to this pipe must still be at least three feet above the bottom of the pond to prevent bottom materials from being re-suspended due to scour (The basin must also be at least 6 to 8 feet deep so the water on the bottom is cooler). A negatively sloped outlet pipe with an inlet that is below the water surface of the pond is one method of discharging from the bottom of the pond. This type of outlet will not be affected significantly by floating debris. As a result, the amount of maintenance that will be required will be reduced.

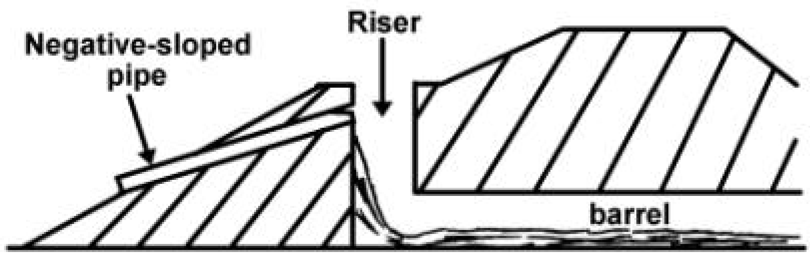

Figure 3.9 - Sub-surface Draw Outlet Structure

There are several potential problems with the design of a wet detention basin:

1. Excessive algae must be controlled to prevent odors, and to maintain nutrient removal capacity. If the aquatic plants are not harvested, the pollutants that have been removed during the growing season will be released when they die in the fall.

2. If the basin is functioning properly, it will be necessary to periodically (about 5 to 10 years) dredge the accumulated sediment. The configuration of the pond should allow easy access to the pond to allow dredging.

3. The water quality within the ponds will be poor. As a result, water contact recreation (such as swimming) should be discouraged.

4. Since the pond will have a permanent pool of water, there may be a local concern about safety. **Except in the vicinity of the outlet structure, the use of fences should be avoided.** The use of fences to try to deny access to a pond will result in the pond not being maintained properly and will likely result in the pond becoming a dumping ground for various types of refuse. It is recommended that the pond be designed and landscaped in such a manner as to discourage easy access to the pond by little children.

5. Using natural wetlands for treating stormwater runoff can modify the hydrologic characteristics of the wetland. It is highly recommended that natural wetlands **not** be used for stormwater treatment. When alternatives are available, the stormwater should be treated before discharging to a natural wetland. It is strongly urged that the District Office of the Land and Water Management Division, Michigan Department of Environmental Quality (MDEQ) be involved early in the planning stage (see Appendix A).

6. If the runoff will contain a high concentration of toxic contaminants, it may be necessary to "pre-treat" the runoff before discharging to the wet pond. (One alternative would involve retaining the runoff on-site). The Surface Water Quality Division of the DEQ may be able to provide some guidance in pre-treating stormwater runoff for toxic contaminants.